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Dominance and diversity studies of vegetation of polluted habitats around Sanganer, Jaipur

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Abstract: 74 plant species belonging to 29 dicot and 4 monocot families were recorded at the polluted habitats around Sanganer during two seasons (Spring and late Rains). Poaceae was the most species rich family, having 12 plant species. The plant species richness in late-rainy season was almost double of spring season. Conversely the total density declined (22-83%) due to toxicity reduction. The values of IVI (103-197) and biomass (320-718 g m^{-2}) for *Cynodon* suggested dominance of this species at all the sites in both seasons. The codominants amongst grasses were *Brachiaria* (IVI = 75, biomass = 65.7 g m^{-2}) and *Paspalum* (IVI = 56-65, biomass = 210-248 g m^{-2}), while amongst forbs they were *Croton, Parthenium* and *Xanthium* (IVI = 21-80, biomass = 91-145 g m^{-2}). Most of the marshy species usually had very low IVI (<5) and low biomass (0.2-11 g m^{-2}). The biomass values during spring (87-848 g m^{-2}) were relatively lower than those in the late rainy season (249-1178 g m^{-2}). The composition responses (density, biomass, IVI) of vegetation at polluted sites are compared with unpolluted sites. Also, possible effects of pollution are discussed.

Resumen: Se regstraron 74 especies de plantas pertenecientes a 29 familias de dicotiledóneas y 4 de monocotiledóneas en habitats contaminandos en los alrededores de Sanganer durante dos estaciones (primavera y final de lluvias). Con 12 especies de plantas, Posaceae fue la familia con mayor riqueza específica. La riqueza de especies de plantas a finales de las lluvias fue casi el doble de la de primavera. Por el contrario, la desnidad total decreció (22-83%) debido a la reducción en la toxicidal. Los valores de IVI (103-197) y biomasa (320-718 g m^{-2}) para *Cynodon* sugieren que esta especie es la dominante en todos los sitios en ambas estaciones. Las codominantes entre los pastos fueron *Brachiaria* (IVI 75, biomasa 65.7 g m^{-2}) y *Paspalum* (IVI 56-65, biomasa 210-248 g m^{-2}), mientras que entre los sufrútices fueron *Croton, Parthenium* y *Xanthium* (IVI 21-80, biomasa 91-145 g m^{-2}). La mayoría de las especies de pantano usualmente tuveron un IVI muy bajo (<5) y una biomasa baja (0.2-11 g m^{-2}). Los valores de biomasa durante la primavera (87-848 g m^{-2}) fueron relativamente más bajos que los de la estación de final de lluvias (249-1178 g m^{-2}). Se comparan las respuestas de la composición (densidad, biomasa, IVI) de la vegetación en sitios contaminados con las de sitios no contaminandos. Asimismo se discuten los posibles efectos de la contaminación.

Resumo: Nos habitats poluídos da zona envolvente de Sanganer foram registadas 74 espécies vegetais pertencendo a 29 dicotiledóneas e 4 monocotiledóneas durante duas estações (primavera e no fim das chuvas). A família das Poaceae foi a mais rica, apresentando 12 espécies. A riqueza em espécies vegetais no fim da estação das chuvas foi quase o dobro da da primavera. Pelo contrário, a densidade total decresceu (22%-83%) devido à redução da toxicidade. Os valores de IVI (103-197) e da biomassa (320-718 g.m^{-2}) para o *Cynodon* sugere a dominância desta espécie em todas os locais e em ambas estações. As codominantes, entre as ervas, eram a *Brachiaria* (IVI = 75, biomassa = 65,7 g.m^{-2}) e *Paspalum* (IVI = 56-65, biomassa = 210-248 g.m^{-2}), enquanto que entre os *Croton*, *Parthenium*, e *Xanthium* os valores encontrados foram: IVI = 21-80; biomassa = 91-145g.m^{-2}). Muitas das espécies dos locais alagados apresentavam um IVI (<5) muito baixo, bem como uma biomassa baixa (0,2-11 gm^{-2}).

da biomassa durante a primavera (87-848 g.m^{-2}) eram relativamente mais baixos do que os encontrados no fim da estação das chuvas (249-1178 g.m^{-2}). As respostas quanto à composição (densidade, biomassa IVI) da vegetação nas estações poluídas foram comparadas com as não poluídas. Os efeitos da poluição são também discutidos.

Key words: Dye wastewater, IVI, marshy vegetation, municipal wastewater, pollution.

Introduction

The water, being a good solvent, is an ideal carrier of both municipal and industrial wastes. As a result, the water courses are considered as the most suitable disposal sites for wastewaters. Presently, the volume of wastewaters is increasing at a fast pace in the country, especially along the river courses, on account of rapid increase in human population, urbanisation and industrialization. Ironically in Class I cities, only 21.67% of sewage is collected, of which 88.61% is treated. The situation in Class II towns is still worse, where only 4.84% of the generated wastewater is collected. Only 42.25% of this is treated (Anonymous 1990). The facilities for the treatment of industrial wastewaters are also inadequate (Gopal & Zutshi 1998). As a result, most of the inland fresh water bodies in the country, lentic as well as lotic, have become polluted, which results into adverse effects on their flora and fauna.

Assessment of impact of water pollution on the aquatic organisms has recently become a favourite subject for investigation in the country (Gopal & Zutshi 1998). Among plants, the effects of water pollution on algae have been investigated in detail (Mallick & Rai 1990; Rai *et al.* 1990; Rai & Mallick 1993; Chaturvedi *et al.* 1999). The studies on higher plants were primarily focussed on uptake of pollutants (Unni & Philips 1990, 1992). The toxicological effects on their growth were rarely examined (Mhatre & Chaphekar 1985; Chawla *et al.* 1989; Sharma *et al.* 1998). It is thus clear that the response of the aquatic ecosystems to water pollution has not received much attention in the country (Gopal & Zutshi 1998), though its importance has been increasingly realised in the context of biodiversity erosion (Alfred & Nandi 1999). This paper examines the responses of marsh vegetation along Amanishah drain (lotic ecosystem) and pool vegetation (lentic ecosystem) at Sanganer. The study focuses on the assessment of impact of pollution on: (i) floristic diversity and dominance of plants at different sites along the drain and dye wastewater pools; and (ii) threatened plant species.

Study area

The Amanishah drain originating from the Aravalli hills N.E. of the Jaipur city (26°49′ - 26°51′ E longitudes), receives sewage of the city and industrial wastewaters of Vishwakarma industrial area. At Sanganer (about 16 kms. south of Jaipur city) it again receives sewage from the town and industrial wastewaters (mostly from textile dyeing and printing industries). Apart from the Amanishah drain, the untreated dye wastewater is also discharged on the land, forming shallow pools (depth = 60-75 cm) adjoining the dyeing units. The effects of the wastewaters on the moist bank vegetation were monitored at six sites in two localities viz. Amanishah drain and dye wastewater pools.

The three sites along the Amanishah drain were selected with reference to the point receiving maximum wastewaters (Fig. 1). This point has been named as Polluted zone (Site-2). The drain at the polluted zone had steep slope, while the vegetal cover along it was sparse, and therefore, this site (S_2) suffered from soil erosion throughout the study period. The site located 2 km preceding to the polluted zone has been referred to as Upstream (Site-1), whereas the other located about 4 km ahead of the polluted zone as Downstream (Site-3). The upstream site receives mainly sewage from the Jaipur city. Unlike polluted zone, the slopes at the other two sites were gentle and the vegetation covers were relatively better, especially at the upstream. These two sites also suffered from soil erosion during rainy season.

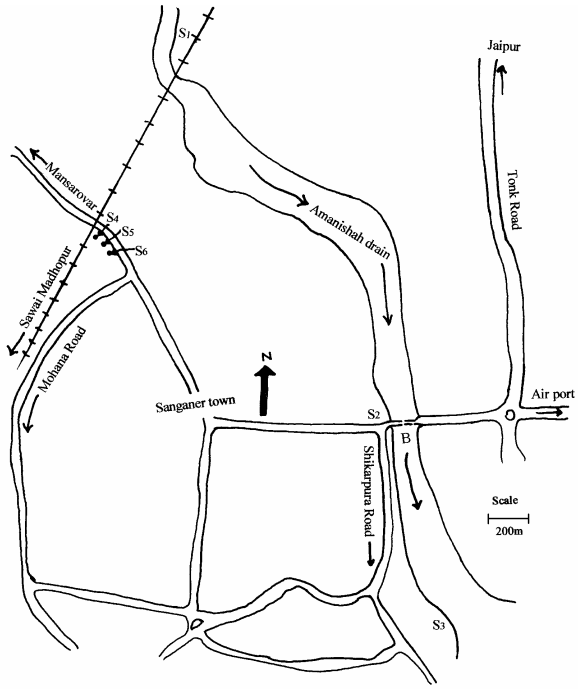

Fig. 1. A schematic map showing study sites along the Amanishah drain (S_1-S_3) and dye wastewater pools (S_4-S_6) in Sanganer; Code : B = Bridge, S_1 = Upstream, S_2 = Polluted zone, S_3 = Downstream, S_4 = Pool 1, S_5 = Pool 2, S_6 = Pool 3.

Amongst three pools (S_4, S_5 & S_6); two (S_4 & S_5) receive wastewaters of aniline and rapid fast azo dyes while the third one (S_6), mostly of procian dyes. Due to the suspension of textile printing activities during rainy season, the sizes of two pools decreased markedly during the studies made in late rainy season (S_4 = 40 x 13 m; S_5 = 50 x 10 m; S_6 = 25 x 10 m) as compared to spring (S_4 = 50 x 25 m; S_5 = 65 x 9 m; S_6 = 50 x 40 m). In general, the biotic disturbances such as grazing and harvest of vegetation were poor, except for upstream (S_1) - harvesting for fodder, and S_5-a part of the vegetation was dug for raising its boundary.

During analysis of physico-chemical characteristics of water in the pools, the water samples were collected from three points in each pool; namely entry point of dye wastewater and two farthest points opposite to the former. Unlike this, the water samples from Amanishah drain were collected only from its three study sites. The water samples collected from the entry point of dye wastewaters in the pools and Amanishah drain (polluted zone), were more polluted than those collected from the other two points at the pools as well as upstream and downstream of Amanishah drain (Table 1).

The analysis of physico-chemical characteristics of soils of both drain and pools revealed higher values during spring, except for Cu in the pool soils (Table 2). The soils were alkaline (pH = 7.6-9.5) with low conductivity (0.10-0.76 m mho/cm) and chloride (3-57 mg/l), except for high conductivity and chloride content of (conductivity >1 m mho/cm; chloride >240 mg/l) pool bank soils during spring.

Material and methods

The studies on vegetation along the drain sites (S_1 - S_3) were carried out in an identified area of approximately 100 m length and 5 m width. Whereas considering definite size of pools, the vegetation growing all around the pool was sampled to assess overall impacts of pollution. However, the sampling points along the moist bank at S_4 and S_6 shifted markedly due to reduction in pool size in the late rainy season. Ten to fifteen quadrats (50 x 50 cm) were laid randomly at 6 sites for phytosociological studies. Investigations were made during spring (Feb. - Mar.) and late-rainy (Aug.-Sept.) season, the two most favourable peri-

Table 1. Physico-chemical characteristics of water in the pool and Amanishah drain.

Locality		pH	Conductivity (m mho cm^{-1})	Chloride (mg l^{-1})	COD (mg l^{-1})	Cu (mg l^{-1})
	Upstream (S_1)	7.8-8.1	1.14-1.45	195-310	41 - 188	0.10
Drain	Polluted zone (S_2)	7.7-8.0	1.10-1.94	280-330	105 - 911	0.35
	Downstream (S_3)	7.6-8.2	1.02-1.62	265-280	53 - 64	0.12
	Entry	2.8-8.7	1.02-4.38	265-510	37.7 -1936	0.06 - 0.37
Pools (S_4-S_6)	Farthest-1	5.8-8.9	1.12-2.26	250-550	113 - 203	0.13 - 5.03
	Farthest-2	4.0-8.2	1.16-2.62	325-740	143 - 376	0.15 - 15.04

Table 2. Physico-chemical characteristics of soil and sediment at different study sites.

Study site		pH	Conductivity (m mho cm^{-1})	Organic matter (%)	Chloride (mg 100 g^{-1})	Cu (ppm)
S_1		8.4 (8.3)	0.76 (0.26)	2.02 (0.18)	57 (3)	12.3 (2.3)
S_2		8.4 (8.5)	0.31 (0.12)	0.40 (0.21)	24 (3)	1.8 (4.7)
S_3		7.6 (7.6)	0.48 (0.11)	1.90 (0.11)	13 (3)	15.1 (2.3)
S_4	Bank soil	8.7 (8.2)	1.13 (0.16)	0.41 (0.46)	283 (8)	7.3 (13)
	Sediment	7 (7.6)	0.12 (0.37)	0.89 (0.97)	10 (8)	56.7 (185)
S_5	Bank soil	8.6 (8.0)	1.03 (0.56)	0.61 (0.98)	245 (33)	6.3 (8.9)
	Sediment	8.3 (7.7)	0.39 (0.26)	0.62 (0.78)	40 (8)	27.2 (108)
S_5	Bank soil	9.5 (8.2)	0.33 (0.1)	0.32 (0.57)	66 (4)	0.45 (6.6)
	Sediment	9.0 (8.4)	0.82 (0.22)	0.47 (0.83)	35 (6)	6.2 (8.7)

Values in parenthesis - late rainy season.

ods for plant growth in the study area. During these seasons, most of the plant species were in flowering, thereby enabling correct taxonomic identification. Individuals of each species were counted in the quadrats for density estimates. For mat forming taxa e.g. *Cynodon* and *Paspalum* density measurements were made in 10 x 10 cm quadrat. Fifteen shoots of each species were brought to the laboratory for measuring their diameters at the base, using a screw gauge. However, for plants with rosette habit (i.e. *Typha* and *Rumex*), the circumference of the shoots, usually a group of leaves at the ground level, was measured. Importance Value Index (IVI) was calculated according to Cottam & Curtis (1956). Coefficient of Similarity among sites was calculated using the Modified Sorensen Coefficient (Southwood 1978).

(i) Modified Sorensen coefficient (Sc) = $\frac{2jN}{aN + bN}$

where, jN = Sum of lesser values of density in two sites; aN = Sum of density of all species in site (a); bN = Sum of density of all species in site (b).

Presence of other plant species (not encountered in the quadrats studied) was also recorded to complete the inventory of each site.

For biomass studies, all plants growing in five randomly selected quadrats at each site, were harvested along with their below-ground organs to a depth of about 30 cm during both seasons and brought to the laboratory in separate polythene bags. Plant material was separated species wise, after washing with tap water to remove the adhering soil, dried in a hot air oven for 7 days of 60°C and weighed.

The impact of pollution was also assessed on fungal flora of the pool bank soils, sediments and water during summer, when their metabolism is considered to be maximum due to high temperature (Godshalk & Wetzel 1978). The fungi were initially isolated by baiting technique, and were later transferred on PDA media for growth. Standard keys were used for their identification (Barnett & Hunter 1972; Gilman 1959).

Results and discussion

In all, 54 plant species (of 25 dicot and 4 monocot families) were recorded in the quadrat studies (Table 3), and 20 species (12 families) from these sites were not encountered in the quadrats. Poaceae (12 species), followed by Asteraceae (8) and Leguminoceae (8) were most species rich families (Table 3).

Cynodon and *Celosia* on account of their abundance in the waterlogged sites in present investigation, need to be considered as marshy species adhering to the definition of wetland/marsh (Cowardin *et al.* 1979). Earlier both of them were not included in the list of aquatic and marshy plants of Indian habitats (Lavania *et al.* 1990). Based on the reports of Rai & Sharma (1991) *Amaranthus*, *Croton, Euphorbia* sp. and *Melilotus* were also considered as wetland species in the present study.

Of the total 30 marshy species, 27 were found in the vegetation of Amanishah drain, whereas 16 species in the pool vegetation (Table 3). *Euphorbia, Sesbania* and *Sonchus*, occurring sparsely at the pools, were absent along the drain. Besides, another 14 species were totally absent at the pools, which may be attributed to their susceptibility towards pollution, especially for dye wastewaters.

Some marshy species, common in both upstream and downstream of Amanishah drain, *Arundo, Celosia, Commelina, Cyperus alopecuroides, Eclipta, Paspalum, Polygonum, Rumex, Saccharum* and *Typha*, were absent from polluted zone, suggesting recovery of marsh vegetation on the downstream. This site also had, in addition to others, *Anagallis* and *Ranunculus* (Table 3). Decrease in toxicity of wastewaters at the downstream may be responsible for this recovery. Similar observations have been reported elsewhere (Gopal & Chamanlal 1991; Ozimek & Sikorska 1976; Pieczynska *et al.* 1975).

Both submerged and free floating plant species were absent both in drain and pools. This can be attributed to the toxicity of the dye wastewaters (Chaturvedi 1999). Occurrence of such taxa in unpolluted pools of the adjoining areas strengthens this assumption (Goel *et al.* 1981). The diversities of algal species were (9-16 species) also lower at these sites (Chaturvedi *et al.* 1999) in comparison to the unpolluted water body such as Ramgarh reservoir (about 30 km from Jaipur), where Gopal *et al.* (1981) reported 35 algal species.

Study on mycoflora of the pools revealed the presence of 10 fungal species (six genera) in water, sediment and bank soil (viz. *A. candidus, A. flavus, A. niger, A. ochacious, F. moniliformae, F. oxisporum* and one species each of *Botrytis, Cladosporium, Penicillium* and *Rhizopus*). The number in the pool water (5-7) were comparable to bank soil (5-6) and sediment (4-8). As such, fungal diversity of the pool water was lower than unpolluted sites like Ghana Bird Sanctuary, Bharatpur (30 species) and Ramgarh lake, Jaipur (17 species). Whereas, for soils it was similar to unpolluted sites (4-7 species, Jain 1985).

During quadrat studies, species richness of the moist bank vegetation during spring (8-17) and late rainy season (16-26) was almost equal at both drain and pool sites, though it increased markedly during the late rainy season, especially at the pools. Amongst the six sites, species richness was maximum at the upstream (17) during spring and on site-4 (26) during the late-rainy season (Table 3). A marked reduction in total density was noted at downstream (24%) and the pools (22-83%) during late rainy season. This was primarily due to reduction in density of *Cynodon* at these sites (downstream = 42%; Pools = 87-90%). This apparently seems to be on account of reduction in toxicity at the pools due to temporary suspension of printing activities, which resulted in greater species richness leading to competition with the existing species, especially *Cynodon*. Whereas, at downstream, this was due to vegetation loss resulting from soil erosion caused by flooding. While comparing, the vegetation at the drain sites revealed less similarity in species composition (21-52%, spring and 23-79%, rains) than among the pool sites (24-65%, spring and 36-87%, rains). This can be attributed to the difference in nature of pollutants at drain sites (at the upstream the vegetation is mostly exposed to sewage at the downstream to both sewage and dye wastewaters)and

Table 4. Similarity coefficient for vegetation growing at different sites in spring and late rainy season.

Sites	Amanishah drain			Pools		
	S_1	S_2	S_3	S_4	S_5	S_6
S_1	1.0 (1.0)	0.50 (0.25)	0.52 (0.79)	0.15 (0.49)	0.30 (0.50)	0.65 (0.17)
S_2		1.0 (1.0)	0.21 (0.23)	0.06 (0.29)	0.02 (0.59)	0.34 (0.38)
S_3			1.0 (1.0)	0.35 (0.48)	0.64 (0.57)	0.69 (0.17)
S_4				1.0 (1.0)	0.62 (0.42)	0.24 (0.36)
S_5					1.0 (1.0)	0.45 (0.87)
S_6						1.0 (1.0)

Values in parenthesis - Late rainy season pool sites (exposed only to textiles wastewaters).

Similarly, coefficient data revealed clear impact of pollution/ habitat modification on vegetation. The polluted site (S_2), except for 59% similarity with S_5 in rains, exhibited relatively low (2-38%) similarity with other sites (Table 4). Higher similarity with S_5 in rains is due to the dominance of *Cynodon dactylon, Cyperus compressus* and *Dactyloctenium aegyptium* in both sites (Table 3).

Considering IVI a measure of dominance, *Cynodon* (IVI = 142-197) in spring dominated the sites, followed by *Chenopodium* at S_1 (IVI = 28) and S_3 (IVI = 43), *Parthenium* at S_2 (IVI = 49), S_5 (IVI = 32) and S_6 (IVI = 31), and *Brachiaria* at S_4 (IVI = 41).

Marked variation in dominance in late rains was observed for site 4 and 6 where *Cynodon* (IVI = 53 at S_4 & 31 at S_6) was replaced by *Brachiaria* (IVI = 75) at site-4 and by *Cyperus rotundus* (IVI = 79) at site-6. At other sites *Cynodon* remained dominant (IVI = 67-117). Next in order were *Paspalum* at S_1 (IVI = 56) and S_3 (IVI = 65), *Parthenium* at S_4 (IVI = 44) and S_5 (IVI = 80) and *Dactyloctenium* (IVI = 73) at S_6.

With the exception of *Cynodon, Cyperus* and *Paspalum*, other wetland species such as *Alternanthera, Ammania, Anagallis, Bacopa, Brachiaria, Celosia, Commelina, Croton, Cyperus compressus, Echinochloa, Eclipta, Euphorbia, Ipomoea, Melilotus, Polygonum, Rostellularia* and *Rumex* usually had low IVI (<5), possibly on account of adverse effects inflicted by pollution on their growth. This view was strengthened by previous studies, which suggest that *Cyperus alopecuroides* and *Polygonum* are sensitive to dye wastewaters (Sharma *et al.* 1998). Also, it was noticed that *Eclipta* plants exhibited better growth under controlled conditions after their transfer to the University botanical garden from the upstream site (authors pers. obs.). These plants are rare and grouped under threatened category (Table 3). Although *Phragmites* and *Typha* are tolerant to pollution (Sharma 1978; Sharma *et al.* 1998), they could not form dominant stands. This is due to erosion caused by frequent changes in the course of drainage, and also their frequent shoot harvest by the farmers.

With regard to biomass (in both seasons) grasses contributed more (42-97%) at upstream (S_1) and downstream (S_3) sites, while forbs (40-93%) at other sites (Table 5). The notables among grasses were *Cynodon* and *Paspalum*, and amongst forbs, *Croton, Parthenium* and *Xanthium*. A special mention can be made of *Parthenium*, which contributed almost 20-50% to the biomass of pool vegetation and about 30% on the polluted zone, during spring. Its share, however, decreased to 10-20% at these sites in the late-rainy season, except for site-5, where it contributed about 35% to the standing crop. This decrease may be attributed to the fact that most of the *Parthenium* plants were in the seedling stage on these sites, except for site-5, where it was a mixed stand of mature shoots and seedlings. At these sites, *Parthenium* grows almost round the year due to availability of moisture, while it dries up in the nearby upland areas during winter. Thus, a relatively longer growth period, starting from its seed germination in the rainy season, helped in attaining higher biomass in the spring season. Several forbs showing higher biomass at specific sites were; *Alternanthera, Chenopodium* and *Polygonum* on site-3 and *Heliotropium* on S_4 (Table 5). Thus, except for *Cynodon*, biomass of most of the marsh species like; *Brachiaria, Commelina, Cyperus, Eclipta, Ipomoea, Paspalum, Phragmites, Polygonum, Rostellularia* and *Typha*, was lower (50-98%) than the values reported in the literature (Vyas *et al.* 1990). This was perhaps caused by pollution on the pools and in case of Amanishah drain mostly by pollution, soil erosion and harvest of shoots in case of *Paspalum, Phragmites* and *Typha*.

Moreover, the total plant biomass was higher at upstream and downstream sites compared to polluted zone and pools in both seasons (Table 5), thereby establishing that dye wastewaters are inhibitory for growth of vegetation. Biomass increased markedly at the upstream, site-5 and site-6 in the late-rainy season, but remained almost similar to spring, at the polluted zone and site-4, despite the increase in species richness (Table 5). The decrease in biomass at downstream in the late-rainy season was, however, due to vegetation loss as a result of soil erosion after flooding in the rainy season.

The present study highlights differences in vegetation composition in response to pollution. During spring season, the impacts of pollution on the vegetation at the polluted zone (S_2) greatly reduce at the downstream. The factors responsible for this state could be the degradation of pollutants in the sludge formed at the downstream promoted by mixing of atmospheric air with the flowing wastewater. Unlike drain, the adverse effects of pollution on vegetation were, however, similar all around the pools during spring season, which decreased during rainy season, when dilution of pollutants caused both by rains and temporary shut down of the printing activity subsided their toxicity. This favours vegetation growth during this period. *Cynodon* among grasses and *Alternanthera, Chenopodium, Parthenium, Verbesina* and *Xanthium* among forbs were the most prominent plant species in the moist bank vegetation, whereas, most of the marshy species were poorly represented. This also holds true for both algal and fungal flora. The occurrence of the exotic forbs such as *Parthenium, Verbesina* and *Xanthium* as codominants in the moist bank vegetation is of great concern, since they may pose a threat to the native species. This study also highlighted the possibility of vegetation recovery, as noted during the late rainy season along both Amanishah drain and pools, following reduction of pollution and biotic disturbances of them.

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